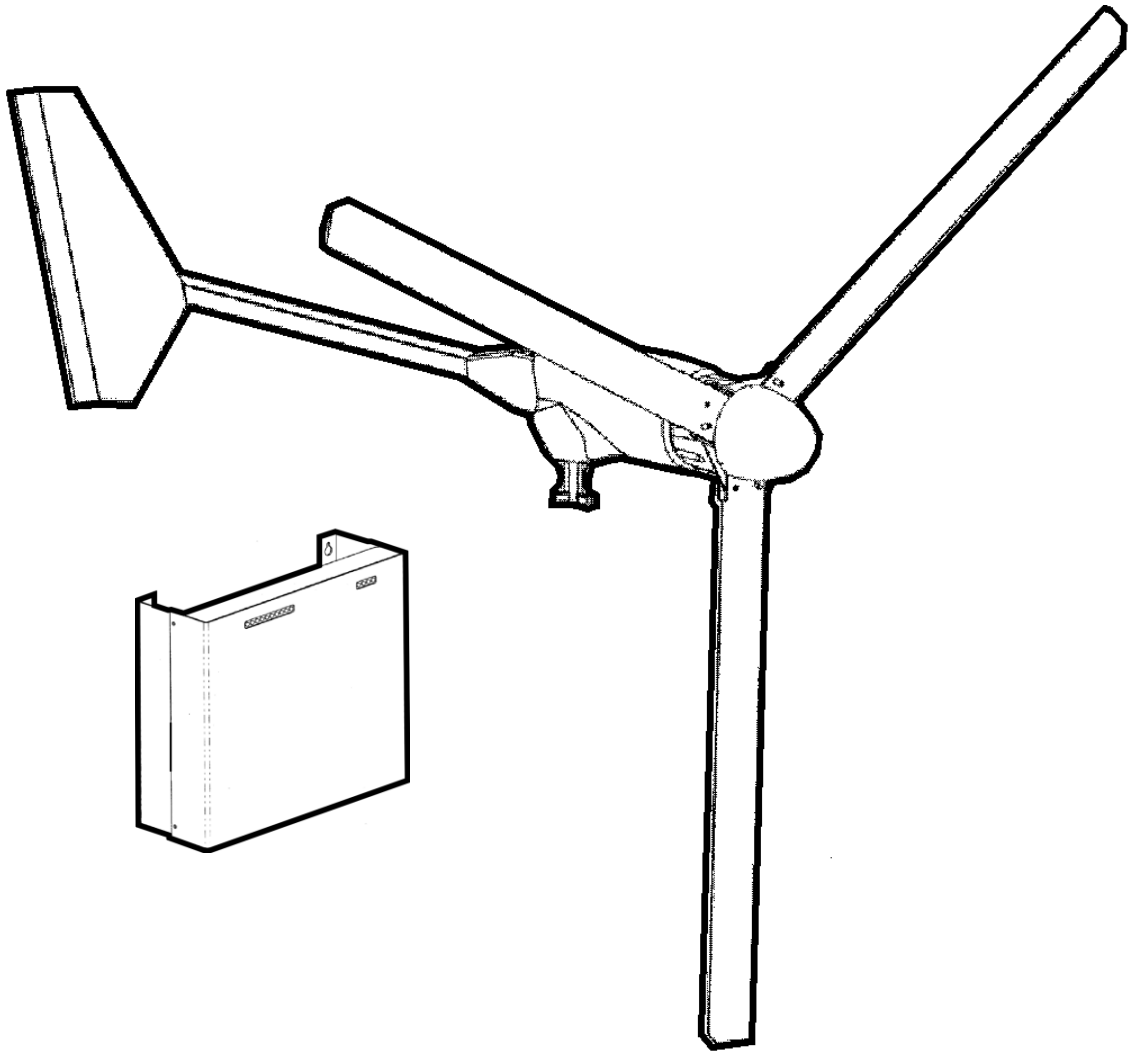
Version 2.2
August 2003

BWC XL.1

24 VDC Battery Charging System

Owners Manual

XL.1 Wind Turbine
PowerCenter Controller



BERGEY WINDPOWER

Bergey Windpower Co.
2001 Priestley Ave.,
Norman, OK 73069 USA
Telephone: (405) 364-4212
Fax: (405) 364-2078
E-mail: sales@bergey.com
Web: www.bergey.com

BWC XL.1 Wind Turbine
24V Battery Charging System

OWNERS MANUAL

Table of Contents

1.	Overview ……...	1
2.	Cautions and Warnings ……..	1
3.	Identification …….	2
4.	System Description ……...	2
5.	System Operation ……..	3
6.	Turbine Installation …….	9
7.	PowerCenter Installation …..	14
8.	Inspections and Maintenance	17
9.	Trouble-Shooting ……..	19
	Installation Planning ……	23
	Common Mistakes ……..	28
	XL.1 Specifications ……	29
	Basic Tower Requirements ..	30

1. Overview

The BWC XL.1-24 wind turbine system is a state-of-the-art small generator designed to charge batteries and supply electrical loads in a 24 VDC DC-bus based remote power system. When used in conjunction with a suitable sine wave DC-AC inverter and a 24 VDC battery bank the XL.1-24 can also be connected to the power grid.

The XL.1-24 turbine consists of a 2.5 meter (8.2 ft.), 34-kilogram (75 lb) wind turbine rated at 1,000 watts and a multi-function turbine and system controller, the PowerCenter.

The XL.1-24 wind turbine features superior low-wind-speed performance, very high system efficiency, and low noise. The PowerCenter features a solar regulator, a dump load capability, an automated time-based equalization function, and special circuitry to boost the low wind speed performance of the XL.1 wind turbine.

The BWC XL.1-24 is offered with the optional guyed tubular Tilt.Tower, which comes in heights from 9 m (30 ft.) to 32 m (104 ft.). The Tilt.Tower is shown in Figure 1. For installation procedures on this tower please refer to the "BWC XL.1 Tilt.Tower Installation Manual". This manual is available on-line at http://www.bergey.com, from BWC dealers, and from BWC directly.

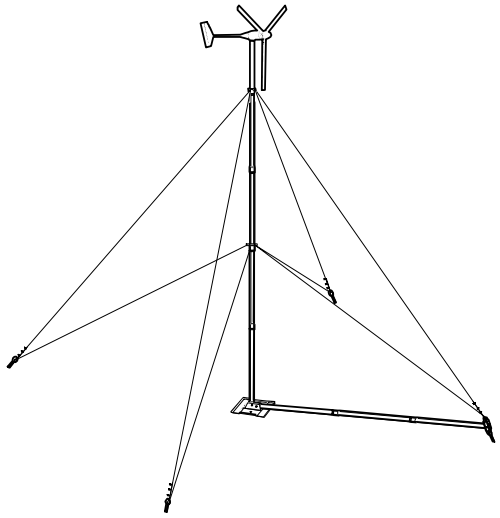


Figure 1, XL.1 with 9 m Tilt.Tower

2. Cautions and Warnings

This manual contains important information on the installation of your BWC XL.1 wind turbine and PowerCenter controller. **We strongly recommend that you read and follow the instructions contained in this manual.**

At several points in the manual items of special interest or significant impact are highlighted by one of the following notices.

Warning

Hazards or unsafe practices that could cause personal injury or death.

Caution

Hazards or unsafe practices that could cause product damage.

Note

Significant points of interest

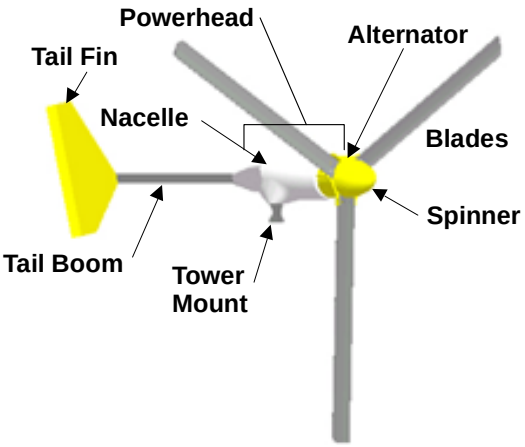


Figure 2, Major Components of the XL.1 Wind Turbine

3. Identification

Each BWC XL.1-24 wind turbine has a serial number decal located on the tower mount. The Serial Number is also written on the box that the turbine came in. We recommend writing it here as well

BWC XL.1-24 Serial No.: _____

4. System Description

XL.1 Wind Turbine Components

The major components of the XL.1 wind turbine are shown in Figure 2.

A. Blades / Rotor System

The rotor system consists of three fiberglass blades. Acting like aircraft wings, the blades convert the energy of the wind into rotational forces that can drive a generator. The airfoil on the XL.1 is the new SH3045 developed specifically for the XL.1 by Bergey Windpower. The fiberglass blades are exceptionally strong because they are densely packed with glass reinforcing fibers that run the full length of the blade. The rotor has three blades because three blades will run much smoother than rotors with two blades.

B. Alternator

The alternator converts the rotational energy of the rotor into electricity. The alternator utilizes permanent magnets and has an inverted configuration in that the outside housing (magnet can) rotates, while the internal windings and central shaft are stationary. The alternator was specially designed for the XL.1 and produces power at low speeds, eliminating the need for a speed-increasing gearbox.

The output from the alternator is three-phase alternating current (AC), but it is rectified to direct current inside the nacelle. Since it uses permanent magnets, the alternator is generating voltage whenever the rotor is turning.

Warning

The output wiring of the BWC XL.1-24 presents a low voltage shock hazard whenever the rotor is turning. Caution must be exercised at all times to avoid electrical shock.

C. Nacelle

The nacelle is the fiberglass housing around the main body of the machine. It contains the main structural “backbone” of the turbine (called the mainframe), the rectifier, the slip-ring assembly, the yaw bearings, and the tower mount. The yaw

bearings allow the wind turbine to freely pivot around the top of the tower so that the rotor will face into the wind.

The slip-ring assembly is the electrical connection between the moving (as it orients with the wind direction) wind turbine and the fixed tower wiring. The slip-rings and yaw bearings are located just above the tower mount. The tower mount attaches the XL.1 turbine to the top of the tower.

D. Tail Assembly and AutoFurl® Operation

The tail assembly, composed of a tail boom and the tail fin, keeps the powerhead (and, therefore, the rotor) aligned into the wind at wind speeds below approximately 12.5 m/s (28 mph). At about 12.5 m/s the AutoFurl® action (see Figure 4) turns the rotor away from the wind to limit its speed. The tail appears to fold, but in reality the tail stays stationary, as the powerhead turns sideways to the wind. The rotor does not, however, furl completely sideways. This allows the turbine to continue to produce power in high winds. When the high winds subside the AutoFurl® system automatically restores the turbine to the normal straight position.

E. PowerCenter

The PowerCenter, shown in Figure 3, serves as the central connection point for the electrical components in the system and it provides a number of necessary and valuable control functions. Not all of the available functions will be used in all installations. The PowerCenter also provides status lights for the system and a handy light-bar "fuel gage" for the battery bank.

Note

The XL.1 wind turbine will not perform properly, particularly at low wind speeds, without the PowerCenter controller. The Power Boost circuitry in the PowerCenter is needed to provide acceptable performance in wind speeds below approximately 7.5 m/s (17 mph).

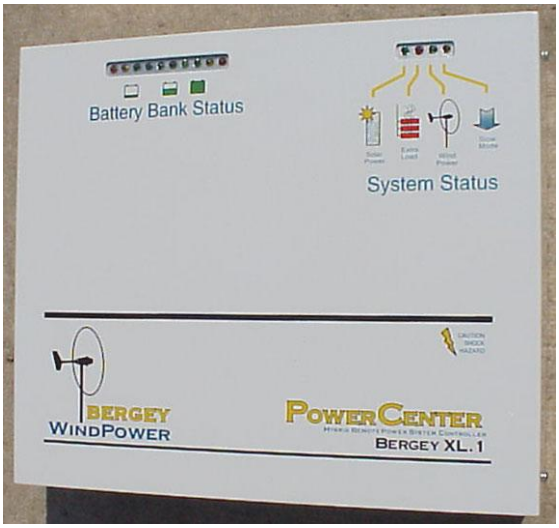


Figure 3, PowerCenter for the BWC XL.1

5. SYSTEM OPERATION

A. Normal Operation

The rotor of the BWC XL.1 should begin to rotate when the wind speed reaches approximately 3 m/s (7 mph). (For the first several weeks of operation, however, the start-up wind speed will be higher because the bearing seals have not worn-in.) Battery charging should commence shortly after the rotor spins up to speed. Once turning, the rotor will continue to turn in lower wind speeds, down to approximately 2.5 m/s (6 mph).

Note

All operational wind speeds given assume steady winds, sea-level altitude and moderate temperatures. Hot weather, high altitude, turbulence, and gusting winds will reduce system performance.

The rotor speed will increase with increasing wind speed and the system will provide a higher output. This output increases rapidly because the energy available in the wind varies as the third power (cube) of the wind speed. For example, if the

wind speed doubles from 5 m/s (11.2 mph) to 10 m/s (22.4 m/s), the energy in the wind increases by a factor of eight ($2^3 = 2 \times 2 \times 2 = 8$). One result of this relationship is that there is very little energy available in light winds. For the average site, winds in the range of 5.5 – 9 m/s (12 – 20 mph) will provide most of the system's annual energy production.

B. High Winds - AutoFurl

During periods of high wind speeds the AutoFurl system will automatically protect the wind turbine. When furled, the power output of the turbine will be significantly reduced. In winds between 13 m/s (29 mph) and 18 m/s (40 mph) it is normal for the turbine to repeatedly furl, unfurl and then furl again. In winds above 18 m/s (40 mph) the turbine should remain continuously furled.

AutoFurl is a simple and elegant method of providing high wind speed protection. The AutoFurl system is based on aerodynamic forces on the rotor, gravity, and the carefully engineered geometry of the wind turbine. As shown in Figure 4, the aerodynamic forces acting on the blades cause a thrust force pushing back on the rotor. This force increases with increasing wind speeds.

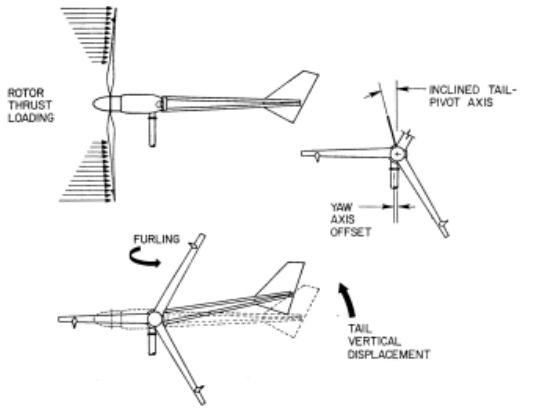


Figure 4, AutoFurl

The thrust force acts through the centerline of the rotor, which is offset from the centerline of the tower pivot axis (yaw axis). Therefore, the thrust force on the rotor is always trying to push the rotor over to the side, away from the wind.

But the rotor is kept facing into the wind at speeds up to ~ 12.5 m/s (28 mph) by the wind turbine's tail assembly. The tail, in turn, is kept straight by its own weight because its pivot at the back of the nacelle is inclined. So the weight of the tail holds it against a rubber bumper and the tail holds the rotor into the wind.

The geometries in the systems are carefully balanced so that at ~ 12.5 m/s (28 mph) the rotor force acting on the yaw-offset is large enough to overcome the preset force holding the tail straight. At this point the rotor will start turning away from the wind or furling. The tail stays aligned with the wind direction. The speed of furling depends on the severity of the wind gusts and whether the wind turbine stays furled depends on the wind speed.

As the wind turbine furls the geometry of the tail pivot causes the tail to lift slightly. When the high winds subside the weight of the tail assembly returns the whole turbine to the straight position. The AutoFurl system works whether the turbine is loaded or unloaded.

The AutoFurl system is completely passive, so it is very reliable and since there are no wear points, like in a mechanical brake system, it is very robust. AutoFurl was used in the very first wind system produced by Bergey Windpower in 1980 and in every unit produced since. AutoFurl is an important element of our success.

There is one situation in the field, however, that we have found can disrupt the operation of AutoFurl. If the wind turbine is installed on a sharp hill or next to a cliff so that the wind can come up through the rotor on an incline (e.g., from below; as opposed to horizontally) we know that this will affect furling and can produce higher peak outputs. We strongly recommend avoiding this situation.

Caution

Do not install the XL.1 wind turbine near cliffs or precipices or on sharp hills such that the wind does not travel horizontally through the rotor.

C. Slow-Mode Operation

As the battery bank voltage approaches the battery regulation voltage, the PowerCenter controller will first try to restrain this voltage by applying the

optional Extra Load (or “dump load”). The Extra Load function diverts current from the battery to an air or water heater. If this measure is not sufficient, or there is no dump load in the system, the PowerCenter will slow the wind turbine and pulse the solar panels on and off to regulate the charge on the batteries.

Slow-Mode prevents the wind turbine from operating without load once the batteries are full. This reduces noise and reduces the likelihood of blade flutter. Blade flutter is loud, short-term, blade vibration that can occur at very high rotor speeds or in severely gusting winds. Flutter will not hurt the system or endanger it, but it can be annoying. Most customers are unlikely to experience blade flutter.

In Slow-Mode, the turbine will be slowed to approximately 130 RPM in low wind speeds, and as the wind speed increases, the operating RPM will be decreased. Maximum power in this mode is 120 watts and the power output will decrease as the wind speed decreases. The speed of the rotor will vary over a limited range as the PowerCenter adjusts turbine output current to maintain the battery voltage within a narrow range. If the load on the batteries increases, dropping battery voltage, the XL.1 will speed up so that it can deliver more charging current. .

If there is no load at all on the system, then the turbine will be brought to a very slow speed, approximately 20 RPM, and the solar panels will be disconnected completely.

D. PowerCenter Controller

The basic electrical schematic for the BWC XL.1 is shown in Figure 5. The XL.1’s alternator produces three-phase alternating current (AC) that varies in voltage and frequency with the rotor speed. The AC power is rectified to direct current (DC) power by a rectifier module inside the nacelle. Thus, the wire run from the wind turbine to the PowerCenter is DC.

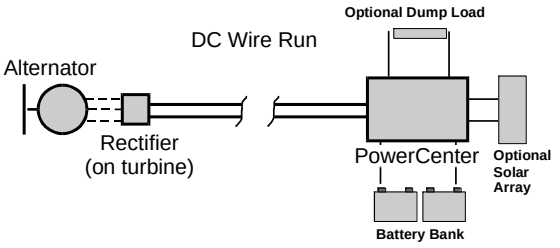


Figure 5, XL.1 Basic Electrical Schematic

The PowerCenter for the XL.1 has two sets of color-coded light-emitting-diodes (LED’s) for System Status and Battery Bank Status.

System Status Lights:

Solar Power (green): Lights up when the optional solar panel(s) are charging the batteries.

Extra Load (red): Lights up when the optional auxiliary or dump load is activated as the batteries approach full charge. When the red LED is lit, the dump load will be heating.

Wind Power (green): Lights up when the XL.1 wind turbine is charging the batteries. A blinking green LED indicates that the low wind speed performance optimizing circuitry (low end boost) is operating.

Slow Mode (yellow): Blinks slowly to indicate that the turbine is being operated slowly to prevent overcharge of the batteries, or because Slow Mode has been manually selected. If pressing the mode selector button has manually stopped the turbine, this LED will blink rapidly, the turbine may still be spinning, but will be stopped as soon as possible. In “Blown Fuse Mode” this LED blinks every second, the same frequency as the Wind Power LED.

Battery Bank Status Lights:

Battery bank charge status is shown with ten colored LED’s, which act like a fuel gage for your remote power system. This gage, however, is inexact and it is intended to provide only a general indication of the energy reserves available in the system. The following table shows the voltage indicated by the highest lit LED and its approximate relationship to the battery capacity available.

LED No. (from left side)	Indicated Battery Voltage Range	Approximate Battery Reserve
L1 (red)	Below 22 V	Below 5%
L2 (yellow)	22 – 23.5 V	5%
L3 (green)	23.5 – 24 V	15%
L4 (green)	24 – 24.5 V	30%
L5 (green)	24.5 – 25 V	60%
L6 (green)	25 – 27 V	90%
L7 (green)	27 – 28 V	100%
L8 (green)	28 – 29.5 V	100%
L9 (yellow)	29.5 – 30.5 V	100%
L10 (red)	Above 30.5 V	100%

Table 1, Battery Bank Status Indications

The LED's provide an indication of the instantaneous battery voltage. This voltage is affected by the state of battery charge and the instantaneous net current flow into or out of the battery. Therefore, during high charging/low load periods the gage will over-predict battery state of charge and during low charging/high load periods the gage will under-predict battery state of charge. Also, the smaller the battery bank the more rapidly the LED's will change in response to changing wind and electrical load conditions.

The PowerCenter is designed to work with flooded-cell or sealed, deep-cycle, lead-acid batteries. Do not use other types of batteries, such as Ni-Cad batteries, without first contacting Bergey Windpower Co.

Mode Selector Button

The button on the backside of the enclosure (see Figure 12) is used to manually select several different modes of operation. If the controller is in any of these manually selected modes press and release the button to exit the mode. To select an optional mode (described below) the mode selector button is pressed and held until the set of 4 System Status or 10 Battery Bank Status LED's indicate the function you desire.

Upon first pressing the mode selector button the Slow Mode LED (yellow) will begin to blink rapidly and will continue for 10 seconds. Releasing the button during this time period applies electrical braking for **Stop Mode**.

If the button is held for longer than 10 seconds, then the Battery Bank Status LED's will begin to blink, indicating battery bank equalization mode. Release the switch during this 10 second period to initiate the **Equalization Function**.

Continuing to hold the mode selector button will cause the voltage indicating LED's to stop flashing and the Slow Mode LED (yellow) will begin to blink slowly, indicating **Manual Slow Mode**. Release the switch during this 10 second period to put the wind turbine into Slow-Mode.

If the mode select button is held still longer (total of 30 sec) then the Battery Bank Status LED's will begin cycling rapidly from no LED's ramping up to 10 LED's and back down again, indicating the **Watt Display** mode. Release the switch during this period to select the watt display function.

If the button is not released during the watt display mode activation then the controller will return to normal operating mode. All LED's will be indicating as would be expected in normal operation and releasing the mode selector button will now have no effect.

Using the PowerCenter Functions (Modes)

Stopping the Turbine

The rotor can be stopped under most wind conditions using the electrical braking function in the PowerCenter. You might use this function, for example, before lowering or climbing the tower. We do not recommend frequent use of the braking function because of the heat stress it puts on the alternator, particularly when the winds are strong. In fact, the PowerCenter software contains "roadblocks" to repeated use of the braking function over a short time.

To initiate stopping simply press the mode selector button and release while the Slow Mode LED (yellow) is rapidly blinking. The turbine should stop quickly. If it does not then the winds may be too high to stop the turbine. As soon as there is a lull in the winds the turbine should stop.

If the PowerCenter cannot stop or slow the turbine after 3 minutes, it will return to normal operation. During the following 5 minutes, the PowerCenter will not allow another attempt to stop the turbine or enter manual Slow Mode.

To release the wind turbine from stop mode click the Mode Selector Button.

Battery Equalization:

Equalization is a maintenance function that brings the batteries up to a higher state of charge and causes them to out-gas (bubble) actively. It should be performed approximately once a month on a windy day.

The PowerCenter has an automatic five-hour battery equalization function that is initiated using the push button on the backside of the PowerCenter enclosure. Press and hold the mode selector button until the battery voltage LED's begin blinking and release the button. When the equalization function is activated the regulation voltage is raised by 2 VDC (30.1 VDC is the factory setting for equalization). During equalization the voltage indicating LED's will blink.

To manually exit equalize mode click the Mode Selector Button.

Note

Equalization will allow the battery bank to reach 30 VDC, which may cause some inverters to shutdown due to "input over voltage".

Caution

Do not equalize sealed batteries. The out-gassing at high battery voltages will damage them.

Always check the electrolyte levels in each battery cell after equalization and add distilled water as necessary. Do not add battery acid. The loss of fluid is due to water being dissociated into hydrogen and oxygen. The sulfuric acid remains. The production of potentially explosive hydrogen gas during hard charging is the reason that battery enclosures should always be ventilated.

Manual Slow Mode:

Normal operation can be overridden and the turbine forced to operate very slowly, but still produce some power using the manual Slow-Mode function. To select this mode press and hold the mode selector button until the Slow-Mode LED begins blinking slowly and release. To exit Slow-Mode, press (click) the Mode Selector Button.

To manually exit manual or automatic Slow Mode, click the Mode Selector Button. You must use the Mode Selector Button to manually exit manual Slow Mode; it will not exit automatically, even if the battery voltage drops significantly.

Watt Display:

To display instantaneous turbine power output, press and hold the mode selector button until the Battery Bank Status LED's begin ramping up and down, and then release the button. You will need to hold the selector button for about 30 seconds before the PowerCenter cycles to this function. After releasing the button instantaneous turbine output power is displayed. Each LED indicates 100 watts; so 5 LED's indicate 500 watts. To exit watt mode, click the mode selector button.

To manually exit watt display mode click the Mode Selector Button.

Blown Fuse Mode

This is an automatic mode that the PowerCenter enters to protect itself if it detects that the main 90-amp fuse has blown or the battery bank has been disconnected. In this mode the turbine will turn slowly (as if in Slow Mode) and the Slow Mode LED will blink at the same rate as the Wind Turbine LED.

To restart the system from this protective mode you will need to click the Mode Selector Button. It will not automatically reset itself. Before manually resetting the system, however, you need to check the 90-amp fuse and the electrical connections to the battery bank. See Page 17 for information on replacement fuses.

The PowerCenter senses a lost battery problem by monitoring the system voltage. It is possible to

fool the PowerCenter if the battery bank is small and the wind gusts are strong. High charging current can raise the battery bank voltage too high for a short period (several seconds) and put the PowerCenter into Blown Fuse Mode. We recommend a battery bank of at least 220 Ah to avoid this possibility. Also if you have a PV array or inverter-charger that could momentarily create a battery voltage above 35 VDC they will initiate the Blown Fuse Mode.

Operation of Controls and Factory Settings

The PowerCenter will automatically switch the XL.1 wind turbine, the optional photovoltaics (PV) array, and the optional dump load on and off to maximize energy capture and prevent battery overcharge. The PowerCenter's microprocessor-based smart controls determines these switching functions based on the battery bank voltage.

At battery voltages below the regulation voltage (factory set at 28.1 VDC), the wind and solar are connected and allowed to charge the batteries. At wind speeds below approximately 8 m/s (18 mph) the turbine LED (green) will blink slowly to indicate that the controller is boosting the voltage from the turbine up to battery voltage. This "low end boost" function ensures that the maximum possible power is extracted from the turbine at low wind speeds, and allows the turbine to produce power down to as low as 2.5 m/s (6 mph) under ideal conditions. In higher winds the turbine produces enough voltage to charge the batteries directly and the boost function is turned off. Once the wind turbines passes out of boost, its green System Status LED will quite blinking and become continuously lit.

If the battery voltage rises above regulation voltage the Extra Load (dump load) circuit is ramped up to control the battery voltage. The maximum allowable resistance load that can be placed on the dump load circuit is 0.5 ohms, producing a maximum current of 60 amps. When the XL.1 and the solar are producing more output than the batteries and dump load will accept, then the PV will be turned off. If the battery voltage continues to rise then the turbine will be put into Slow-Mode operation.

In Slow-Mode the maximum turbine power is 120 watts, if the dump load and batteries can use more power, then the PV will be cycled on and off to provide as much power to the dump load and batteries as possible.

While in Slow-Mode, if there is no dump load, the turbine will be slowed as the batteries come up to a full state of charge. If some additional electrical load is turned on, the turbine will increase its speed up to approximately 130 RPM, to provide more power in order to keep the batteries topped up.

Slow-Mode is exited after the battery voltage remains below regulation voltage minus 1.5 VDC (factory setting of 26.6 V DC) for 13 minutes. Slow-Mode is also exited if there is a large load placed upon the system that pulls the voltage down to regulation voltage minus 2.5 VDC (25.6 VDC factory setting) for 25 seconds.

The PV will be turned on anytime the controller senses that the dump load is not at maximum power, and there is sufficient sunlight. While in Slow-Mode there is no preference for either the XL.1 or the PV, if the controller decides that it needs more power when it is deciding to turn the PV on or off, then the PV will be turned on. Likewise for the turbine, as the PowerCenter decides whether or not to increase the RPM and power from the turbine it looks at the battery voltage at that instant. This control of the two sources optimizes the two resources to keep the batteries at a peak state of charge.

The Extra Load (dump load) is Pulse Width Modulated (PWM). Effectively this gives "infinitely" variable adjustment of the voltage applied to the attached load. The load resistance controls the maximum current that is drawn, and no load should be connected that will draw more than 60 amps. In this system amperage, voltage, and load resistance are related by the formula:

AMPS = 30 V / RESISTANCE

Any dump load resistance higher than 0.5 OHMS will work with the PowerCenter controller. Smaller dump load resistances will overload the circuitry and may damage the PowerCenter. Note: not all multi-meters will accurately measure the resistance at such low values. Suitable dump loads must also be designed and installed such that they will not overheat and/or cause a fire hazard.

To determine the required heat dissipation rating of the heater (resistor), calculate the AMPS as

above and then calculate the required wattage. It is recommended that the dissipation rating be at least 10% higher than this figure:

WATTAGE = AMPS x AMPS x RESISTANCE

Caution

Do not connect too large of an Extra Load (greater than 60 amps). The PowerCenter may be damaged. If you do not understand the above equations, please call Bergey Windpower for assistance.

Warning

FIRE HAZARD

DO NOT use a dump load that is not safely isolated from all potential sources of combustible materials or fuels, including wood mounting boards and hydrogen out-gassing from the batteries.

Put another way a dump load rated 60 amps at 30 volts is the largest that can be used. Multiple loads can be connected in parallel as long as the sum of their individual currents does not exceed 60 amps.

Due to the PWM feature some Extra Loads may be noisy. The noise comes from the high-frequency switching and it will only be heard when power is being delivered to the dump load.

Regulation voltage: The regulation voltage is factory preset at 28.1 VDC, which is appropriate for flooded-cell lead-acid batteries. We do not recommend changing this setting unless you have a compelling reason to do so. Improper voltage regulation settings can lead to either under-charging and shorter battery life or over-charging and shorter battery life.

If a different regulation voltage is necessary based upon the battery manufacturer's recommendations, the following procedure allows easy adjustment.

1. Using a multi-meter set to volts, connect the black lead to the "BAT –" terminal, or touch the terminal marked "TEST 2" on the circuit board.
2. Touch the red lead to the terminal marked "TEST 1".
3. The multi-meter should indicate the regulation voltage divided by 10; for instance, the factory setting is 28.1 VDC, so on "TEST 1" you will read 2.810 VDC.
4. To adjust, use a screwdriver to turn the trim pot labeled "R501". To increase the regulation voltage, turn the pot clockwise. Check the voltage on "TEST 1" and adjust R501 until "TEST 1" reads the desired regulation voltage divided by 10.

6. Turbine Installation

Appendix 1 is an Installation Planning Guide. It provides recommendations on tower heights and locations, electrical components, and wiring. **Please read the Appendix page on "How to Avoid the 6 Most Common Mistakes when Installing an XL.1".**

Tower Mounting: The XL.1 wind turbine is attached to its tower by a three-sided, six fastener casting, shown in Figure 6, that is designed to fit inside a tube with an inner diameter of 108 mm (4.25 in). (Note: XL.1's shipped prior to September 2003 were built to fit a tube with an 85 mm (3.35 in) inner diameter.)

If you are using the BWC Tilt.Tower then the XL.1 will bolt directly in place. If you are mounting the XL.1 to a different type of tower then you will need to ensure that the tower meets the requirements for XL.1 towers (see Appendix) and that it has a proper adapter fitting for attaching the XL.1 tower mount casting (also defined in the Appendix).

Once you have the proper mounting arrangement you can proceed with assembly of the wind turbine. The fasteners on the XL.1 are all metric.

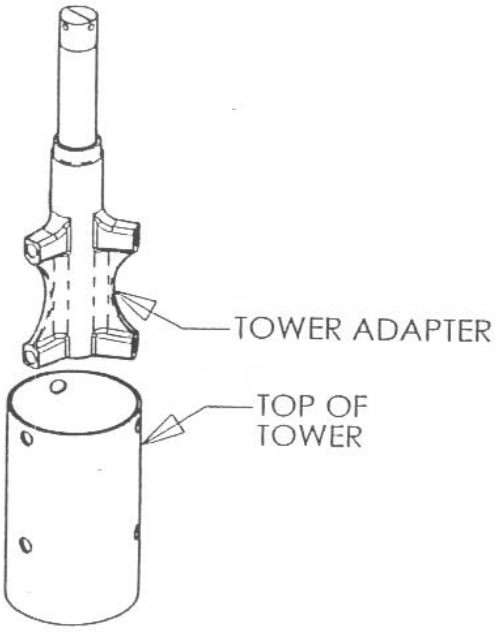


Figure 6, Tower Mounting for the XL.1

Tilt-up Type Towers: If you have a tilting tower, such as the BWC Tilt.Tower, the following procedure is recommended:

Tools Required:

- 17 mm box end wrench
- 17 mm socket and ~ 300 mm (12") ratchet drive
- 8 mm socket or wrench
- pliers
- crimpers for wiring terminals (U-shaped crimp preferred over straight crimp)
- thread locking compound (like Loctite 242)
- tape measure, 12 ft.

Procedure:

Step 1:
With the tower tilted down, place the powerhead of the wind turbine near the top end of the tower.

The tower wiring is connected to the XL.1 wind turbine at the slip-ring using two small screws and ring terminals crimped to the two conductors. BWC does not supply these ring terminals. Cut the outer insulation on the wire back about 60 mm (2.5 in). Strip the insulation off the outer 12 mm (1/2 in) of each conductor and crimp on the appropriate ring terminals. Attach the two power conductors to the slip-ring assembly with the screws provided. The polarities of the connections are marked. If your conductors are color-coded we recommend making note of the colors connected to positive and negative leads.

Caution

Do not use the box lugs supplied for the PowerCenter connections instead of ring terminals. The box lugs could short circuit against the tower tube and damage the alternator.

Caution

Be very careful with the washers on the slip-ring terminals. DO NOT let them fall into the alternator. If they do, you must disassemble the alternator and remove them before completing the installation.

The slip ring assembly is not designed to support the weight of the down-tower wire. A strain relieving installation is required, as shown in Figure 7. If possible put a loop in each wire to wrap around the wire ties. Use the two nylon cable ties provided to secure the tower wiring to the tower adapter casting. After completing the connections, pull on the tower wire to make sure that it is secure before mounting the wind turbine on the tower.

Step 2:
Raise the tower about 1 meter (3 ft) off the ground to provide room to assemble the XL.1 turbine. We recommend fashioning a temporary support stand to hold the tower up during turbine assembly.

Step 3:
Mount the wind turbine tower adapter to the top of the tower using the six M10 x 35mm bolts and six washers. We strongly recommend applying Loctite 242 (Thread Locking Compound) to the threads prior to installation to reduce the likelihood of loosening due to vibration. We recommend using a torque wrench to achieve the proper fas-

tener torque on the tower mounting bolts. The recommended torque is 54 N.m (40 ft-lbs).

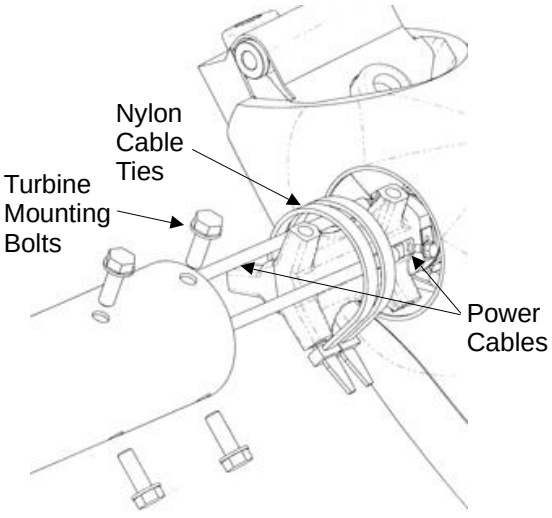


Figure 7, Turbine Mounting

Step 4:
Complete the turbine wiring to the PowerCenter before adding the blades. This is recommended so that you can test the DC polarity of the wiring by spinning the alternator by hand. It is very important that the polarity [positive (+) and negative (-)] is correct when the turbine is connected to the PowerCenter. The best way to ensure this is to complete the wiring and then test the polarity with a Volt-Ohm-Meter or the polarity checker built into the PowerCenter. Do not use the polarity checker on the PowerCenter circuit board with blades on and the turbine turning under wind power because the voltage will be too high for the polarity check circuitry.

To use the PowerCenter's polarity check, first connect the suspected negative wire to the terminal marked "TUR - ", then touch the wind turbine positive wire to the "POLARITY CHECK" pad on the controller. The green LED should light when the alternator is turned by hand. If it does, connect the turbine positive wire to the "TUR +" terminal. If the red LED lights, reverse the leads and check again.

Wiring recommendations are provided in Section 7 and in Appendix 1, section D. Turning the alternator by hand will provide enough voltage to make this check. Carefully mark the positive and negative electrical leads for later reference.

We recommend that you connect the battery bank to the PowerCenter at this point so that you can use the Stop Mode to keep the blades from turning during the turbine and tower raising process.

To connect the battery leads, first connect the battery negative (-) wire to the terminal marked "BAT –". With the battery positive wire touch the pad marked "POLARITY CHECK", if red LED (D80) lights, the connections are backward, double check everything to find the cause. The green LED (D70) should come on, if it does leave the wire in contact with the "POLARITY CHECK" pad for 5 seconds to charge all capacitors and avoid a spark when making the battery connection. Quickly connect the battery positive wire to the terminal marked "BAT +". The system will not operate correctly and could be damaged if the polarity is reversed.

See "PowerCenter Connections" beginning on Page 14.

Step 5:
Bolt the tail fin to the tail boom using the eight M5 bolts and washers provided, as shown in Figure 8. We recommend applying Loctite to the bolt threads prior to assembly.

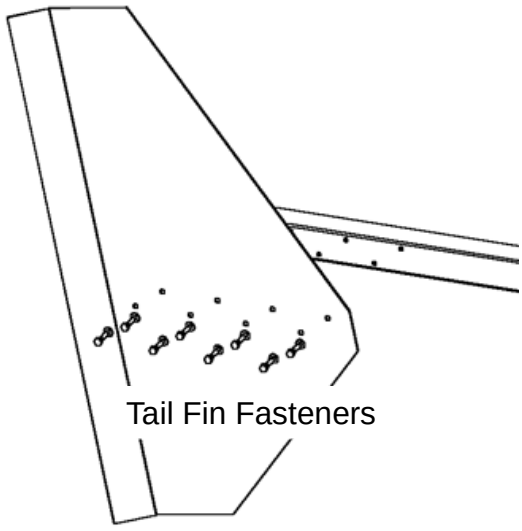


Figure 8, Tail Fin Attachment

Step 6:
Place the tail boom on the rear of the turbine powerhead and insert the 12 mm (1/2") tail pivot pin from the top. If the parts are aligned properly the pin should insert easily. Do not use a hammer to pound the pin in place, as this may cause scoring of the bronze bushings. Secure the tail pivot pin with two flat washers and cotter pins, as shown in Figure 9. Note: Failure to properly install and secure both cotter pins will lead to loss of the tail boom. Let the tail hang down so the turbine head turns part way up for easier blade assembly.

Step 7:
Attach the blades as shown in Figure 10 using the M10 hardware provided. Note that the alternator will actually be hanging upside down at this point, not turned upward as shown in Figure 10.

We recommend bolting one blade up solidly and leaving the other two somewhat loose while you check the tip-to-tip blade distance. We recommend checking, and adjusting as necessary, the blade tip spacing to ensure that the blade tips are equally spaced. This step will help make the wind turbine as smooth running as possible, which will maximize the operating life of the bearings and reduce vibration related noise. The blade tip-to-tip distances should not differ by more than 12 mm (1/2") for smooth operation.

We recommend using a torque wrench to achieve the proper fastener torque on the blade nuts. The recommended toque is 54 N.m (40 ft-lbs). Loctite is not necessary on the blade fasteners because the nylon locking nuts provide adequate locking.

For XL.1's shipped after September 2003 all of the blade bolts are the same length.

Step 8:
Attach the spinner (nose cone) using the three M5 bolts and washers provided, as shown in Figure 10. We recommend applying Loctite to the bolt threads prior to assembly.

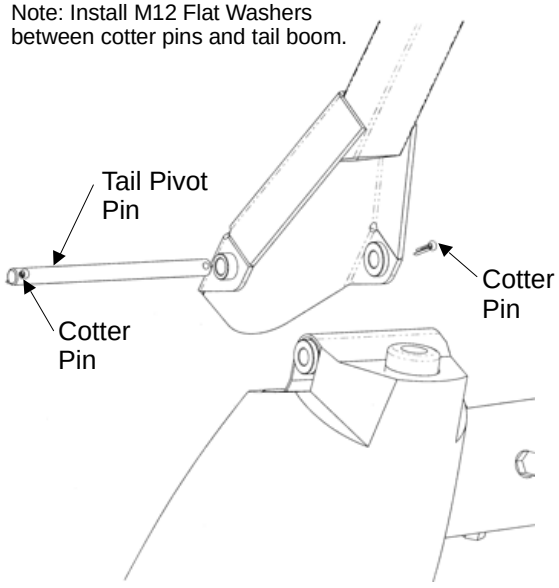


Figure 9, Tail Boom Attachment

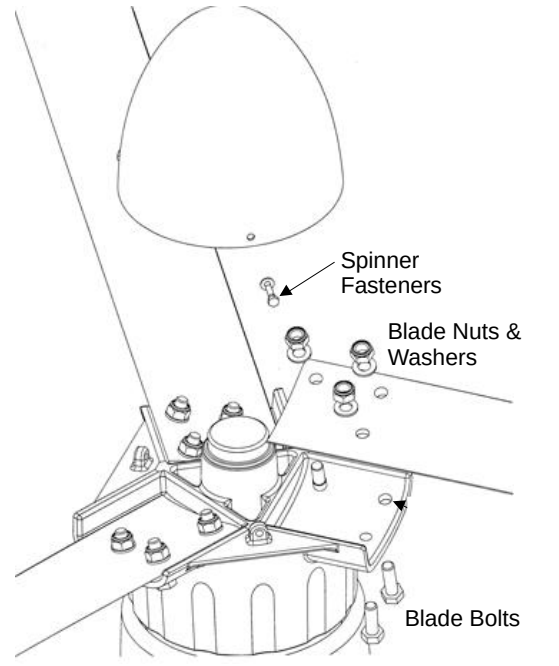


Figure 10, Blade and Spinner Fasteners

Step 9:
Check the XL.1 wind turbine carefully to make sure that the installation is complete. We recommend the following checklist:

- ❑ Blade fasteners are secure and properly torqued
- ❑ Blade tips are evenly spaced
- ❑ Spinner is secure
- ❑ Tail fin is secure
- ❑ Tail pivot pin is locked in place with both cotter pins.
- ❑ Tower adapter bolts are secure
- ❑ Wiring polarity is tested and marked

Step 10:
Dynamically brake the XL.1's alternator by either of two methods: 1) using the Stop Mode function of the PowerCenter, if you already have the turbine and battery bank connected to the PowerCenter, or 2) connecting the positive (+) and negative (-) output leads together. The resulting short-circuit will keep the rotor from spinning during tower raising. DO NOT raise the wind turbine without first stopping the rotor from turning.

To use the Stop Mode of the PowerCenter press the Mode Selector Button on the backside of the PowerCenter briefly. Clinking the button again will release the wind turbine. We recommend verifying that the turbine is in Stop Mode, by checking for resistance to turning the rotor by hand, before raising the tower.

Step 11:
Raise the tower following the procedures outlined by the tower supplier. **Please make safety your top priority.**

Non-tilting Towers: On a non-tilting tower, such as a fixed guyed tower or a self-supporting pole type tower, there are two general approaches that can be used: 1) assemble the tower and turbine together on the ground and then use a light-duty crane to set the tower in place, or 2) erect the tower and then lift the wind turbine to the top with either a light-duty crane or a gin-pole.

A gin-pole, in this case, is a tower assembly tool that attaches to the tower and provides an arm with a pulley so that parts can be hoisted above the top of the tower. Gin-poles are used by professional tower erectors and we do not recommend their use by non-professionals. We know of at least one homeowner who died approximately fifteen years ago while improperly using a gin-pole to install a small wind turbine (though not a Bergey turbine).

Wherever possible we strongly recommend assembling the tower and turbine on the ground. In this case please follow the general procedure for turbine assembly provided in the preceding section. When raising the tower you must lift the tower, not the XL.1 wind turbine. The XL.1 cannot support the weight of the tower.

For customers installing a BWC XL.1 on an existing fixed tower we recommend that you use a crane to lower the tower so that you can attach the turbine on the ground. Alternatively, we recommend you use a bucket-truck, like the type used by utility linemen. Check with local sign companies because they often offer bucket-truck services at reasonable hourly rates. If neither of these approaches is possible then we recommend that you engage the services of professional wind turbine or tower erectors to install your wind turbine.

7. PowerCenter Installation

A. Electrical System

The general electrical configuration for BWC XL.1 and hybrid system installations is shown in Figure 11. In most cases the loads will be AC (alternating current) and they will be supplied through a DC-to-AC inverter.

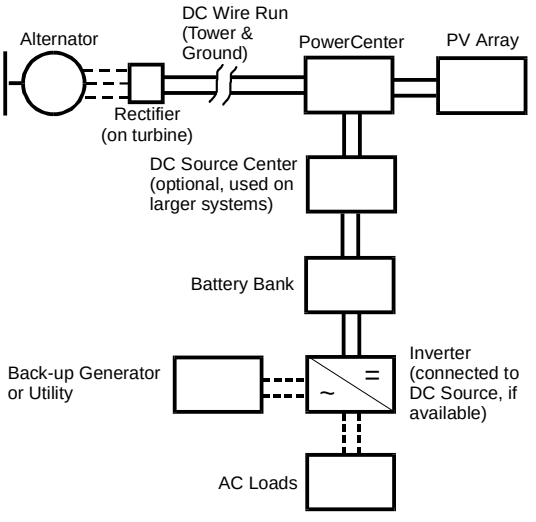


Figure 11, Typical XL.1 System Configuration

The PowerCenter has a limited current carrying capacity so we recommend that you use a DC Source Center whenever you have multiple XL.1 wind turbines. DC Source Centers are available from Bergey Windpower and from other sources.

Additional Design Guidance:

1. If you have multiple XL.1 turbines and PowerCenters, do not connect more than one wind turbine to one PowerCenter.
2. Connect multiple PowerCenters to a DC Source Center via the PowerCenter's battery terminals.
3. Do not connect the PowerCenter to another controller that could disconnect the PowerCenter from the batteries. The PowerCenter should not be disconnected from the battery when there is input from the wind turbine.
4. Do not connect the PowerCenter to the batteries through diodes

B. Location

The PowerCenter must be installed indoors and should be located relatively close to the battery bank. Do not install the PowerCenter outdoors; it is not waterproof.

C. Mounting:

The PowerCenter needs to be mounted vertically to a wall, or other support structure, so that air can pass unobstructed through the passive cooling channel behind the enclosure. We recommend setting the height of the LED's at eye level if possible so that the system status lights will be easiest to read.

The enclosure dimensions and mounting layout for the PowerCenter are shown in Figure 12. The PowerCenter should be mounted with four M4 (0.157" dia.) screws. We recommend the following procedure:

Tools Required:

- Pencil
- Carpenters level
- Drill with ~ 2 mm or 0.09" dia. drill bit
- (4) M4, 1/8", or 5/32" screws
- Screwdriver

Procedure:

Step 1:
Mark the mounting hole locations using the PowerCenter enclosure as the template. Use a carpenters level to check the levelness of the enclosure before marking the holes.

Step 2:
Drill small (~ 2.5 mm or 0.1 in diameter) pilot holes for the mounting screws.

Step 3:
Screw the top two mounting fasteners into the wall until ~ 6 mm (1/4") of the shank extends out from the wall.

Step 4:
Remove the PowerCenter cover and place the PowerCenter enclosure on the two upper mounting fasteners. Slide the enclosure down such that the fasteners are placed at the top of the inverted "T-slots".

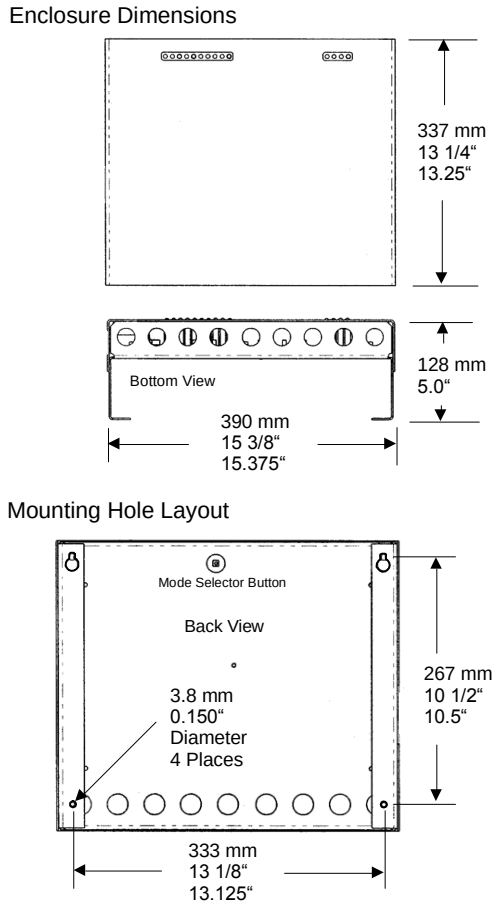


Figure 12, PowerCenter Mounting Dimensions

Step 5:
Install the bottom two mounting fasteners, and then tighten the top two fasteners.

C. Wiring

All wiring should conform to the National Electric Code or other governing local electrical code. The use of electrical conduit for wiring between components is highly recommended. If you have any connections with dissimilar metals (aluminum to copper) they should be coated with an anti-oxidation compound to prevent galvanic corrosion. All loads should be protected by fuses or circuit breakers to avoid hazards from accidental short circuits.

The wind turbine tower must be well grounded and a good quality lightning surge arrestor, connected to a good quality earth ground, should be installed on the wiring from the wind turbine. We recommend a Delta LA302DC arrestor installed into the third (from the left) rear entrance hole of the enclosure. This tucks the arrestor neatly behind the enclosure. The arrestor leads are connected to the wind turbine terminals.

The PowerCenter does not have a built in ground, all circuits are floating, such that either the positive or the negative can be grounded. Some inverter manufacturers recommend grounding and some electrical codes require it. If you do ground the PowerCenter, please conform to local practices for grounding either the positive or negative bus.

All negative leads are connected together on the PowerCenter circuit board, so grounding the battery negative lead, will ground the turbine negative, the PV negative, and the dump load negative as well. This is the preferred grounding method; the enclosure should also be grounded, by bolting a box lug to it in a convenient location.

D. PowerCenter Connections

Cable Entrances: As shown in Figure 13, wiring can be connected to the PowerCenter from below or behind or in a combination of both. A total of eighteen 7/8” (20 mm) entrance holes are provided.

Box Lugs: The PowerCenter is supplied with box lugs (not shown in Figures 13 and 14) that are used to connect electrical leads to the terminals on the PowerCenter circuit board. These lugs can accommodate wire sizes from 35 mm^2 to 10 mm^2 (8 AWG to 2 AWG). **DO NOT use these lugs for the wiring connections to the wind turbine at the top of the tower.**

Plastic Grommets and Plugs: The PowerCenter is supplied with a number of plastic grommets and plugs for the wire entrance holes at the bottom of the enclosure. Grommets should be used to protect incoming wires from the hard edge of the aluminum case. They are not necessary if you are using conduit or special cable entrance fittings. Holes not used for wiring should be sealed using the plastic plugs. Even though 24 VDC is generally not considered a lethal voltage, most electrical codes will require that the unused entrance holes be sealed and we believe that this is the prudent and safest course of action.

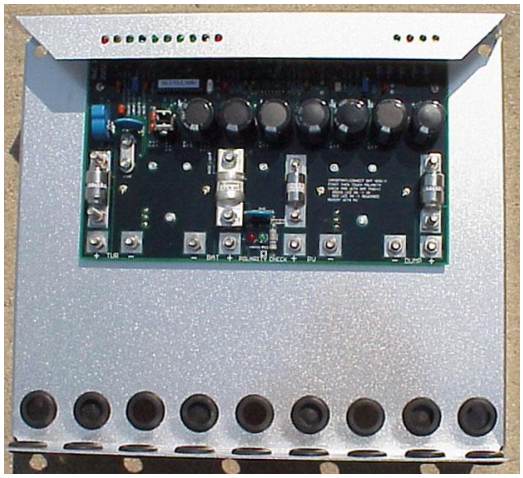


Figure 13, PowerCenter with Cover Removed

We recommend the following procedure for making the electrical connections. **Please ensure that the wires do not pull on, or flex, the circuit board.**

Step 1:
Remove the cover to expose the circuit board and terminals. The terminals are on the circuit board, as shown in Figure 14.

Figure 14, Terminals for Electrical Connections

Step 2:
Connect Dump Load leads. This is an optional resistance-heating load that will operate when the batteries are full. Polarity is not important in making this connection. Connecting the extra load can be done at any time, but if the batteries are full then there will be power on the terminals. This will cause a spark when attempting to make this connection

The specifications for the dump load are explained on page 8.

If you have already connected the wind turbine and battery bank following the recommended procedure for installing the wind turbine, you can go to Step 5.

Step 3:
Connect Battery leads. First connect the battery negative (-) wire to the terminal marked "BAT –". With the battery positive wire touch the pad marked "POLARITY CHECK", if red LED (D80) lights, the connections are backward, double check everything to find the cause. The green LED (D70) should come on, if it does leave the wire in contact with the "POLARITY CHECK" pad for 20 seconds to charge all capacitors and avoid a spark when making the battery connection. Quickly connect the battery positive wire to the terminal marked "BAT +". The system will not operate correctly and could be damaged if the polarity is reversed.

The maximum current to the batteries will be ~ 60 amps with no PV and up to ~ 90 amps with the maximum allowed PV array size. Wiring to the batteries must be sized accordingly (minimum 25mm^2, 4 AWG)

Step 4:
Connect Wind Turbine leads. The turbine leads should still be shorted from the turbine installation. In order to make the connections to the PowerCenter a small wire can be connected to allow the turbine wires to remain shorted until the wires are fully connected to the circuit board. Ensure that the wind turbine wires are connected with the proper polarity. Once both turbine leads are connected, remove the shorting wire. If there is sufficient wind then the turbine will begin turning and the turbine LED will begin blinking, indicating that the turbine is charging the battery.

The system will not operate correctly if the polarity is reversed. The polarity should have been checked with a Volt-Ohm-Meter when the turbine was being installed. If the turbine is installed with reversed polarity, it will spin very slowly, provided that the wind is sufficient. To check for reversed connections with the turbine spinning slowly, place the red lead from a multi-meter on the "TUR +" terminal, and the black lead of the meter to the "TUR –" terminal. The voltage will read minus 0.7 VDC if the turbine is connected with reverse polarity.

Before continuing with the install, click the mode selector button to stop the turbine, and prevent the dump load from being energized.

Step 5:
Connect PV leads. Please ensure that the PV leads are connected with the proper polarity. The system will not operate correctly and could be damaged if the polarity is reversed. First connect the PV negative wire to the terminal marked "PV-", then touch the PV positive wire to the "POLARITY CHECK" pad on the controller, the green LED should light, if it does, connect the PV positive wire to the "PV +" terminal. If the red LED lights, stop and double-check everything for reverse polarity.

The LED indicating that the PV is charging will light in a few seconds assuming that there is sufficient sunlight.

The maximum current capacity of the PV regulator circuit on the PowerCenter is 30 amps. However, please note that PV modules can exceed their rated power under some conditions and we do not recommend connecting more than 750 Watts of PV to the PowerCenter.

Caution

Over sizing the PV array will damage the PowerCenter and void the warranty coverage.

Make sure that PV panels have blocking diodes (Schottky diodes) installed to prevent reverse current flow through the panel.

Step 6:
Connect Inverter. If the system includes a DC to AC inverter, connect the inverter input leads to the battery terminals or DC source center, not to the PowerCenter. The PowerCenter circuit board is not designed to handle the high currents that are possible with inverters. Make sure that there is a fuse between the batteries or DC bus and the inverter.

Step 7:
Connect Loads. If the system includes 24 VDC loads, connect them to the battery terminals or DC source center. Do not connect them directly to the PowerCenter.

Step 8:
Click the mode selector button to release the turbine, and begin operating the turbine.

The XL.1 wind turbine system is now ready to operate. We recommend that you verify that the XL.1 is producing power by putting the PowerCenter in Watt Display mode (see Page 7). In all but the lightest of winds, you should see indication of varying wattage coming from the wind turbine.

8. Inspections and Maintenance

The BWC XL.1 installation should be inspected after 30 days and then again 180 days after installation. Following these two inspections the installation should be inspected every two years and after any particularly severe weather. In corrosive marine environments more frequent inspections are recommended. Inspections should be done on days when the wind is below 7 m/s (16 mph).

Check List for Inspections

1. Inspect each of the anchor points. Ensure that all hardware is secure and the guy wires are properly tensioned. Check to ensure that no strands are broken.

2. Stop the alternator by clicking the mode selector button to place the PowerCenter into Stop Mode. Once the rotor is stopped, climb or lower the tower. Always use proper safety belts and lanyards when climbing.

Warning

Only qualified personnel with proper safety equipment should climb the tower. Never climb the tower when the rotor is turning.

3. Inspect the blades for:

   A. Condition of the leading edge, particularly out near the tip.
   B. Tip damage.

4. Remove the spinner. Check the torque on the blade nuts; the recommended value is 54 N.m (40 ft-lbs). Check the front bearing cover for seal integrity and grease loss. Check the alternator bearings for lack of play, a tiny amount of play is acceptable and normal, if it appears excessive, pop the front bearing cover off. This will expose the bearing adjustment nut. Remove the cotter pin and tighten the nut to just snug. **DO NOT USE A WRENCH**, if the cotter pin will go through one of the two holes in the alternator shaft then push it through, if not **BACK THE NUT OFF (CCW)** until a cotter pin will go through. Replace the front bearing cover. Reattach the spinner and check that it is secure.

5. Check the screws holding the nacelle rubber bumpers and tail fin in place.

6. Check the cotter pins on the tail pivot pin.

7. Check the torque on the tower mounting bolts; the recommended value is 54 N.m (40 ft-lbs).

8. Check for cracks or loose hardware on the tail boom and fin.

9. While descending the tower or before raising it, inspect the following:

   A. Check that the tower wiring is properly secure.
   B. Check all tower fasteners.
   C. Look for any cracks in the tower structure.
   D. Check the condition of the guy wire attachments.

10. Check the connection on all ground rods and hardware.

11. Inspect the surge arrestor(s). Replace if there are signs of damage.

12. Restart the turbine.

13. Listen to the sound of the machine as it speeds up. No mechanical sounds, such as a "clunking" or "banging," should be heard. Also watch for any new or significant vibration. Some “growling” from the alternator is normal. The turbine operation should be smooth.

14. Inspect the wire run, particularly all electrical connections.

15. Check condition of all wiring connections into and out of the PowerCenter.

Preventive Maintenance

We recommend that the bearings be re-packed (re-greased) every 8-12 years. There are four tapered roller bearings, two for the alternator and two for the tower adapter. They are all the same size (Timken L44643/L44610), except for the lower yaw bearing on XL.1’s shipped after September 2003. There are two bearing seals and we recommend that these seals be replaced when the bearings are re-packed.

The strength of the blades, particularly at the root (inner) end, may degrade over time due to flexure and UV degradation of the fiberglass material. The symptom of degradation is a reduction in blade stiffness fore-and-aft. The blades have to become very flexible in the fore-aft direction before there is any risk of tower strikes during severe weather. We recommend that you check blade stiffness about every 10 years and replace the blades if they become extremely flexible.

PowerCenter Fuses

The PowerCenter has four fuses. If you blow (fail) one or more of these fuses you may replace them using the following specifications and parts identifiers (P/N means part number):

Battery Fuse: 90-amps; Buss P/N JJN-90 or Little Fuse P/N JLLN-90

Turbine Fuse: 70-amp or 75-amp; special order because of the L-shaped mounting tabs, but you can use a Buss P/N JJN-70 or Little Fuse JLLN-70 by also installing 2 x M6 brass nuts per post (before placing the new fuse) to accommodate the straight tabs on the stock fuse.

Dump Load Fuse: 60-amp or 63-amp; Buss P/N JJN-60L or JJN-60, or Little Fuse JLLN-60, using 2 x M6 brass nuts per post as described for the Turbine Fuse.

Solar Fuse: 30-amp; Buss JJN-30L or JJN-30, or Little Fuse JLLN-30, using 2 x M6 brass nuts per post as described for the Turbine Fuse.

9. Trouble-Shooting Problems

The following guide can be used to pinpoint the cause of operational problems with the BWC XL.1 wind turbine and the PowerCenter controller. For problems or symptoms not found in the following listing, please contact the Service Department at Bergey Windpower Co. at:

Tel: 405-364-4212
Fax: 405 364-2078
e-mail: pieter@bergey.com

PROBLEM	CAUSE(S)	DIAGNOSIS	REMEDY
Battery voltage gets too high.	PowerCenter regulating voltage set too high	Excessive battery gassing. Use voltmeter to check battery cell voltages or hydrometer to check the specific gravity – compare to battery manufacturers recommendations.	Adjust battery regulation voltage as on page 9
	During operation without dump load, battery voltage can vary up to 1 volts above reg. voltage for a few seconds when in Slow Mode	Use multi-meter to indicate battery voltage	Normal operation, OK for flooded lead acid batteries. For sealed batteries recommend adjusting the set voltage lower, or use a dump load which will allow very precise regulation
Batteries do not reach full state of charge.	PowerCenter regulating voltage set too low.	Use hydrometer to check the specific gravity of the battery cells. Compare with battery manufacturer's recommendation.	Adjust battery regulation voltage as on page 9
	Loads are too large.	Remove largest load. If battery bank reaches higher state of charge, then the system is overloaded.	Consult with BWC about possible remedies.

PROBLEM	CAUSE(S)	DIAGNOSIS	REMEDY
Rotor turns, but the system doesn't charge the batteries.	Blown Turbine fuse	Check voltage across fuse with turbine spinning, should be near zero volts DC.	Replace fuse
	Blown output fuse	Lights on PowerCenter erratic, dump load light stays on, check battery fuse with multi-meter	Replace 90A battery fuse on PowerCenter circuit board. Check battery connections.
	Power transistor failure.	Turbine voltage is above 10 VDC and Turbine light is on, but no current is being delivered.	Return complete PowerCenter to BWC for repair.
	Turbine rectifier failure, possible damaged stator winding	Check voltage from the turbine.	Replace rectifier assembly, or stator
Rotor is unbalanced, causing the turbine to move slightly back and forth as it spins.	Blade tips not evenly spaced.	Check tip-to-tip distances with a tape measure. They should be within 6.5 mm (¼").	Loosening one blade at a time, adjust the tip spacing to bring distances within specifications.
	Ice build-up on blades.	Visual inspection. Severe icing is very obvious.	Take no action. Do not stand under machine. The ice will be shed when there is sufficient sun and wind.
Wind is higher than 16 mph, but rotor will not turn, or turns slowly	Batteries are full, and dump load was at maximum power for more than 5 seconds, without being able to maintain regulation voltage	Slow Mode LED blinking slowly	Normal operation. Turn on big loads, turbine will restart if the battery voltage is 1.5 V below regulation voltage for 13 minutes or 2.5V below regulation voltage for 25 sec
	Short in power leads.	Check connections first. Isolate power leads. Use VOM to check for short circuit.	Repair short circuit.
	Power transistor or MOV (varistor) failure.	Disconnect turbine from PowerCenter. Turbine should start.	Return complete PowerCenter to BWC for repair.

		Disconnect turbine and check with diode meter. Should read ~ “1 V” in one direction and “OL” in the other direction.	Replace rectifier.
PROBLEM	**CAUSE(S)**	**DIAGNOSIS**	**REMEDY**
PV is not on, even though sun is shining.	Dump load at 97% capacity or higher	Turn on additional loads to pull down battery voltage. See if PV turns on.	Normal operation.
	PV hooked up backwards.	Check polarity.	Reverse leads.
	PV fuse blown.	Check fuse with VOM.	Replace fuse.
Dump load does not work.	Fuse blown.	Check fuse with VOM.	Check resistance of dump load, should be no less than 1/2 ohm. Replace fuse.
	Voltage below regulation.	Check battery bank voltage with VOM. If it is below regulation voltage (“TEST1” x 10) the dump load should not be coming on.	Normal operation.
Dump load comes on during automatic generator charge, preventing the batteries from taking a bulk charge	Dump load set to come on at 28.1 Volts, Inverter set to bulk charge batteries at a higher voltage	During charge, battery voltage limited to 28.1 V, Extra Load LED lit	Manually put PowerCenter in Equalize Mode Contact BWC for help

Appendices

Appendix 1

Installation Planning

The location and height of the tower for the BWC XL.1 wind system will be important factors in determining the overall performance of the system. Average wind speed is influenced by many things and may vary considerably within a relatively small region, particularly in complex terrain. Site and tower choice, however, are often limited by such factors as zoning restrictions, property size, proximity to neighbors, customer preferences, and wiring costs. All of these factors should be taken into consideration in choosing the best tower site and height.

A. Legal Restrictions and Good Neighbor Relations

One of the first steps in planning an installation is to determine the legal status of the proposed wind turbine installation in the community in which it will be installed. In most cities and some counties an installation will be subject to zoning laws and building codes. Some neighborhoods have protective covenants that limit the types of home improvements. In areas requiring permits the installation must be planned weeks to months in advance to allow time for applications to be processed and, if necessary, hearings to be held.

The quickest way to determine the local codes and requirements is to call or visit the office of the building inspector. Few cities have specific regulations dealing with wind turbines, but most will have height restrictions, building code requirements, and a formal process for obtaining a building permit. The most common problem encountered in the United States is a height restriction of 10.7 meters (35 feet), particularly in residentially zoned areas.

The 9 m (30 ft) Tilt.Tower meets the 35 ft restriction, but it does so at some loss in performance. If you need or want to go higher than the zoning height restriction you must apply for a variance. A variance is essentially permission to break a rule and it is granted following a public hearing before a Planning Board. Obtaining a variance is a major undertaking, costing $200-5,000 and taking several months, so it is important to establish whether it will be necessary as soon as possible.

Bergey Windpower Co. has experience in working with customers and BWC dealers in variance hearings and we offer advice and assistance to those who request it.

Generally, in order to obtain a building permit you will be required to submit a plot plan and fill out an application. A plot plan is a map, drawn to scale, of your property showing the boundaries, dwelling(s) and other structures, major topographic features, easements, and, most importantly, the location and height of the proposed wind turbine tower. Often you will be required to submit plans for the tower and information on the wind turbine. In some cases you will also be required to submit a structural analysis of the tower to show that it is in compliance with the building code. Sometimes a registered Professional Engineer (PE) must sign this analysis and occasionally the PE must be licensed in the State where the unit will be installed.

Bergey Windpower Co. has engineering analyses, PE-Certified, for most towers it offers and copies of these analyses are available to our customers. Noise data is occasionally required and will soon be available for the XL.1 from Bergey Windpower Co.

If your property size is several acres or more then the turbine will likely be so far from the nearest neighbor's house that they will not be bothered. It is, none the less, strongly recommended that you contact your nearest neighbors well in advance of any construction to let them know that you are installing a wind turbine. This is doubly good advice if your property size is less than several acres or you have to obtain a variance for a building permit. Good neighbor relations boil down to treating your neighbors the same way you would like to be treated and showing respect for their views. An example of what not to do is to put the turbine on your property line so that it is closer to a neighbor's house than to your own and not give those neighbors any advance notice of your intentions.

<u>In general, we do not recommend that a BWC XL.1 be installed on property of less than one-half acre in size.</u> We say this because the impact of a wind turbine on the neighbors in such a "tight" area is significant and the potential for disputes is too great.
If you have questions about procedures, requirements, or tactics, please contact us. Since so few

wind systems have been installed and communities are generally unfamiliar with them, you may face some obstacles in gaining permission to install a unit. We appreciate the pioneering spirit and resolve demonstrated by our customers and we stand ready to help out in any way that we can.

B. Towers

The smooth flow of the wind over the land is interrupted by obstructions and topographical variations. These interruptions bring about two important phenomena: **wind shear** and **turbulence**. Wind shear describes the fact that close to the ground the wind is slowed down by friction and the influence of obstacles. Thus, wind speed is low close to the ground and increases with increasing height above the ground. Wind shear is more pronounced over rough terrain and less pronounced over smooth terrain. Turbulence is essentially rough air caused by the wind passing over obstructions such as trees, buildings, or terrain features. Turbulent air reduces energy output and puts greater strain on the wind turbine.

The effects of both wind shear and turbulence diminish with height and can be largely overcome simply by putting the machine sufficiently high above the ground. Taller towers usually will provide better economics because the power in the wind increases as the cube of the wind velocity ($P = V^3$; e.g., a 26% increase in wind speed doubles the energy output). A small increase in average wind speed will result in a large increase in long-term energy output.

Table 2 shows the influence that tower height can have on annual energy output for the BWC XL.1 wind turbine under typical DOE Class 2 inland site conditions with a shear exponent of 0.20. Wind speed may increase more radically with tower height in hilly or wooded areas. In flat open areas, power production will increase less significantly with tower height.

The BWC XL.1 wind turbine must be placed on a tower that is tall enough to give the rotor proper exposure to the wind. Putting a wind turbine on a tower that is too short is like installing a solar system in the shade. As a "rule-of-thumb" the BWC XL.1 should be 9 m (30 ft) above obstacles within 50 m (160 ft), particularly in the prevailing wind direction. So, the minimum recommended tower height is 9 m (30 ft.). For most situations, a tower of at least 18 m (60 ft.) is recommended for this unit.

Tower Height (meters)	Average Wind Speed (m/s)	Relative Energy Production
9 m	4.8	100%
13 m	5.2	121%
19 m	5.6	147%
25 m	5.9	165%
32 m	6.2	186%

Table 2: Variation in wind speed and expected relative energy output with tower height.

We do not recommend mounting the BWC XL.1 to a home and we suggest caution if installing one on a larger, more substantial, building. Our concerns are 1) the forces on the turbine and mounting system are substantial and homes are not designed structurally for them, 2) the air flow around and over a home or building is complex and can cause considerable turbulence, and 3) the wind turbine will cause vibrations that will be amplified through the home's structure.

BWC offers a guyed-tubular tilt-up tower, the Tilt.Tower, for the XL.1 in heights form 9 m (30 ft) to 32 m (104 ft). The Tilt.Tower is cost-effective and is designed to be installable by non-experts. The installation of these towers is covered in the BWC XL.1 Tilt.Tower Installation Manual. BWC is working to expand the range of tower options, including self-supporting towers that do not require guy wires.

Customers can also supply their own towers. These towers have to meet certain criteria for strength and blade clearance (see Appendix), and a mounting adapter for the XL.1 wind turbine will need to be designed and fabricated. Customer supplied towers are not covered by the BWC warranty and any damage to the XL.1 wind turbine resulting from a customer supplied tower is excluded from the turbine warranty coverage.

C. Location

The size and layout of the installation site may limit the tower location, height, or type. More often than not, however, there are several potential

sites. In choosing the best one, the following factors should be considered:

1. The proximity of the proposed site to dwellings.

As noted before, it is a good idea for you to consult with neighbors about the installation before proceeding. The rotor system and alternator do produce a certain amount of sound. This is a low-level whirring sound that usually can not be heard indoors. From a noise standpoint, the further the wind turbine is from a house the better. In general, we recommend that the turbine be installed at least 18 meters (60 feet) from the house. Most often the tower is installed 18 - 50 meters (60 - 160 feet) from the owner's house. Never choose a site that is closer to a neighbor's home than to your own.

2. The local elevation at the tower site.

Since system performance improves with increased wind turbine elevation it is sometimes best to site the tower on a hill or ridge to gain extra height. If, as is often the case however, the hill or ridge is a considerable distance (more that 100 meters or 330 ft.) from the house the additional wiring costs may more than offset the performance gain to be realized. It is often less expensive to avoid the hill and simply chose a taller tower installed closer to the house.

3. The length of the wire run.

While is possible to install wire runs (the wiring between the wind turbine and the wind turbine electronics) of several hundred meters (650 ft) or more, the costs for long wire runs, particularly if they are buried, can be prohibitive. The longer the wire run, the larger and more expensive the wire that is required to conduct the electricity with acceptable losses. As a general rule, wire runs over 100 meters (330 ft.) if buried or 200 meters (650 ft.) if installed overhead should be avoided because of their high costs. On the BWC XL.1 it is not possible to use transformers to increase the wire run voltage because the wire run is direct current (DC). Transformers only work with alternating current (AC).

4. General convenience.

Often the most compelling consideration for locating the wind turbine tower is the space where it will not interfere with vehicle traffic, fence lines, crops, gardens, septic system lateral lines, power poles, etc. Since the wind turbine installation is semi-permanent, your future plans for the property should also be taken into consideration. When using a Tilt.Tower you should consider the extra space needed for the tower when its is tilted down.

5. Safety

The BWC XL.1 should never be installed close to a power line. We recommend that the tower be at least 1 ½ times the height of the tower from any power line including any overhead service line bringing power to your home.

Warning

The wind turbine towers are typically made of metal, which readily conducts electricity. If any part of the wind turbine or tower makes contact with power lines there is a risk of electrocution.

We also recommend that any guy wire anchors be kept away from roads or paths used by vehicles.

D. Wiring

The basic electrical schematic for the BWC XL.1 battery charging system is shown in Figure 5.

The wind turbine alternator produces 3-phase AC, which is rectified into DC in the nacelle. A two (2)-conductor wire is needed between the wind turbine and the PowerCenter controller. The PowerCenter has a fuse for the wind turbine input, so a fused-disconnect switch is not required at the base of the tower (as is recommended for the other BWC wind turbines).

We recommend that the tower wiring be with SO cord. The SO cord's neoprene jacket will provide

good abrasion resistance. For ground runs we recommend THHN wire buried inside plastic conduit rated for electrical service. A suitable watertight junction box should be installed at the base of the tower to enclose the wire connections between the tower and underground wiring.

In some cases it will be possible to provide direct point-to-point wiring between the XL.1 wind turbine and the PowerCenter. For this purpose we recommend 2-conductor VNTC (Vinyl Nylon Tray Cable), which is suitable for outdoor and direct-burial applications. For rocky soils, or runs underneath roadways, we recommend that the underground wire run be installed in conduit. If a wiring junction is made at the base of the tower then a watertight junction box should be installed for the connections.

The recommended wire sizes for the 24 VDC XL.1 wind turbine are shown in Table 3. The listed distances include the height of the tower.

Maximum Current: 60 amps

Caution

Installing wire sizes larger than those recommended will increase the maximum current produced by the turbine.

WIRE SIZE		DISTANCE FROM TURBINE TO POWERCENTER	
MM^2	AWG	METERS	FEET
10	8 AWG	0 - 35	0 - 116
16	6 AWG	36 - 56	117 - 183
25	4 AWG	57 - 89	184 - 292
30	3 AWG	90 - 112	293 - 368
35	2 AWG	113 - 141	369 - 464
50	1 AWG	142 - 178	465 - 585
55	1/0 AWG	179 - 225	586 - 739
70	2/0 AWG	226 - 287	740 - 940
95	3/0 AWG	288 - 361	941 - 1185
120	4/0 AWG	362 - 455	1186 - 1494

Table 3: Recommended Wire Sizes for the XL.1

Note: These wire sizes have been engineered to provide optimum rotor loading for the BWC XL.1/24 wind turbine. Deviation from these recommendations can result in decreased performance from your machine and / or unnecessary additional wire-run costs. The use of a wire gage one size larger than the recommended size is recommended if aluminum wire is used.

Before assembling the wind turbine the tower wiring must be in place, though not necessarily permanently affixed. We recommend that you leave at least 30 cm (12 in) of free wire at the top of the tower for making the electrical connections to the wind turbine.

E. Other System Components

A complete remote power system will include other electrical components such as a solar array (optional), a battery bank (required), a dump load (optional), and an inverter (optional). These components are sometimes called the “balance of system” or BOS equipment.

The wind turbine and the other BOS equipment are electrically connected in a “DC-bus” architecture, as shown in Figure 6. The DC-bus architecture is robust and very flexible, allowing endless options for multiple and differing components. The unifying feature is that all of these components are electrically connected to the positive (+) and negative (-) DC bus, so they all experience the same DC voltage. The DC voltage of the system is largely determined by the state of charge of the battery bank and to a lesser, but still significant, extent by the charging or discharging rates (the rate at which DC current, or amps, is being created or consumed).

Charging components, such as wind turbines, solar arrays, and inverter/chargers (powered by a back-up generator or the power grid), can be added to a DC-bus system with separate charge regulators and these regulators can operate completely autonomously (e.g., they do not need to communicate with each other or be coordinated using a central system controller). The separate charge regulators, whether there is just one or if there are a dozen, will respond to the DC-bus voltage and control their generators charging current.

When putting together or adding to a DC-bus remote power system there are a few pitfalls to avoid if possible:

- Battery banks that are too small, so that battery voltage swings too much with high charging or discharging currents.
- Multiple charge regulators set to the same voltage, so that there is one big

step in charging current rather than several smaller ones.

- Setting high voltage regulation points too low so that the batteries don't get fully charged
- Setting the low voltage disconnect (typically part of the inverter) too high so that the battery bank capacity is underutilized

How to Avoid the 6 Most Common Mistakes when Installing an XL.1

1. **DO NOT use the PowerCenter box lugs to connect wiring to the turbine**. There is not enough space for them, so they will rub the tower and eventually develop a short circuit. Use crimp-type ring lugs.

Use These

Not These

2. **DO use the built-in polarity checker when connecting the battery leads to the PowerCenter**. Connect either battery lead to the Neg. (-) battery terminal on the PowerCenter, and then touch the other lead to the Polarity Test Point. A green LED is good, a red LED shows that the polarity is reversed. Do Not connect your test wire to the Pos. (+) terminal. Use the same procedure when connecting PV to the PowerCenter. Please note that the Neg. (-) Battery terminal is on the LEFT side, while the Turb. Neg. (-) terminal is in the RIGHT side.

3. **DO NOT install a circuit breaker between the PowerCenter and the battery bank or DC bus.** The original PowerCenter has a circuit breaker for the wind turbine and the new PowerCenter has internal fusing. Using a circuit breaker on the output of the PowerCenter can allow the PowerCenter to be open-circuited under high output condition, which can damage the system. If you are using a Trace Power Panel, Do Not connect the wind turbine to the PV Array Disconnects in the DC Disconnect Box. Do connect the Bergey PowerCenter to the "top" of one of the Battery Disconnects (Pos.) and the Grounding Block (Neg.).

4. **DO NOT install the wind turbine close to a steep slope or cliff.** If the wind can blow up at an angle as it hits the wind turbine the furling will be hampered and the turbine will experience excessive loads and vibration. This is most important from the prevailing wind direction. Try to keep the tower at least two tower heights back from steep slopes.

5. **DO use thimbles on all guy wires and position the lower malleable clip close to the thimble so that the guy wire "captures" the thimble securely.** Not using thimbles or not securing them can lead to guy failure and tower **collapse.** Thimbles are not required on knuckle-end anchors, such as double-eye and triple-eye anchors.

6. **DO follow the recommended wire sizes for your wire run from the wind turbine to the PowerCenter.** With the XL.1 oversizing the wire is a bad thing because it will cause excessively high currents during high winds. Normally, over sizing wire is a good thing – but not in this case.

Appendix 2 XL.1 SPECIFICATIONS

TURBINE:

• ROTOR DIAMETER	2.5 M	8.2 FT
• OVERALL LENGTH	2.1 M	6.9 FT
• TURBINE WEIGHT	34 KG	75 LB
• TURBINE THRUST	890 N	200 LB
• RATED POWER		1,000 W
• RATED WINDSPEED	11 M/S	24.6 MPH
• RATED ROTOR SPEED		490 RPM
• START-UP WINDSPEED	3 M/S	6.7 MPH
• CUT-IN WINDSPEED	2.5 M/S	5.6 MPH
• FURLING WINDSPEED	13 M/S	29 MPH
• MAX DESIGN WINDSPEED	54 M/S	120 MPH
• MAX RUNNING CURRENT	60 AMPS	
• MAX SHORT CIRCUIT CURRENT	120 AMPS	

POWERCENTER:

• WIDTH	365 MM	14.375 IN
• HEIGHT	311 MM	12.25 IN
• DEPTH	125 MM	5 IN
• WEIGHT	3.5 KG	7.75 LB
• MOUNTING: 4 HOLES, DIA =	4.8 MM	.188 IN
• MOUNTING HORIZ. CTR-CTR	332 MM	13 IN
• MOUNTING VERT. CTR-CTR	267 MM	10.5 IN
• CONDUIT ENTRANCES	22.3 MM	.875 IN
• CONDUIT ENTRANCE LOCATION	BOTTOM (9)	BACK (9)
• TURBINE INPUT FUSE	70 AMPS	
• BATTERY FUSE	90 AMPS	
• PHOTOVOLTAIC INPUT FUSE	30 AMPS	
• DUMP LOAD FUSE	60 AMPS	

WIRE SIZING RECOMMENDATIONS:

• BATTERY TO CONTROLLER	25 MM^2	4 AWG
• DUMP LOAD	16 MM^2	6 AWG
• PV PANEL (MINIMUM)	10 MM^2	8 AWG
• TURBINE TO POWERCENTER	SEE TABLE BELOW	

WIRE SIZE		DISTANCE FROM TURBINE TO POWERCENTER	
MM^2	AWG	METERS	FEET
10	8 AWG	0 - 35	0 - 116
16	6 AWG	36 - 56	117 - 183
25	4 AWG	57 - 89	184 - 292
30	3 AWG	90 - 112	293 - 368
35	2 AWG	113 - 141	369 - 464
50	1 AWG	142 - 178	465 - 585
55	1/0 AWG	179 - 225	586 - 739
70	2/0 AWG	226 - 287	740 - 940
95	3/0 AWG	288 - 361	941 - 1185
120	4/0 AWG	362 - 455	1186 - 1494

Appendix 3

BASIC TOWER REQUIREMENTS

For the BWC XL.1 Wind Turbine

Customer supplied towers for the BWC XL.1 Wind Turbine should meet the following minimum requirements:

Tower Height: 9 m (30 ft) minimum, though we recommend 18 m (60 ft) or higher

Design Wind Speed: 54 m/s (120 mph)

Turbine Weight: 34 kgs (75 lbs)

Maximum Turbine Thrust Load: 890 N (200 lbs) @ 54 m/s (120 mph)

Blade Clearance: Top 1.1 m (44 in) of the tower must not exceed 12.7 cm (5 in) radius from the tower center line

Dynamics: Not considered due to variable rotor speed

Stiffness: Tower top should not deflect more than 15 cm (6 in) @ 54 m/s (120 mph)

Turbine Mounting: Cylindrical, 108 mm (4.25 in) Outside Dia. See attached drawing

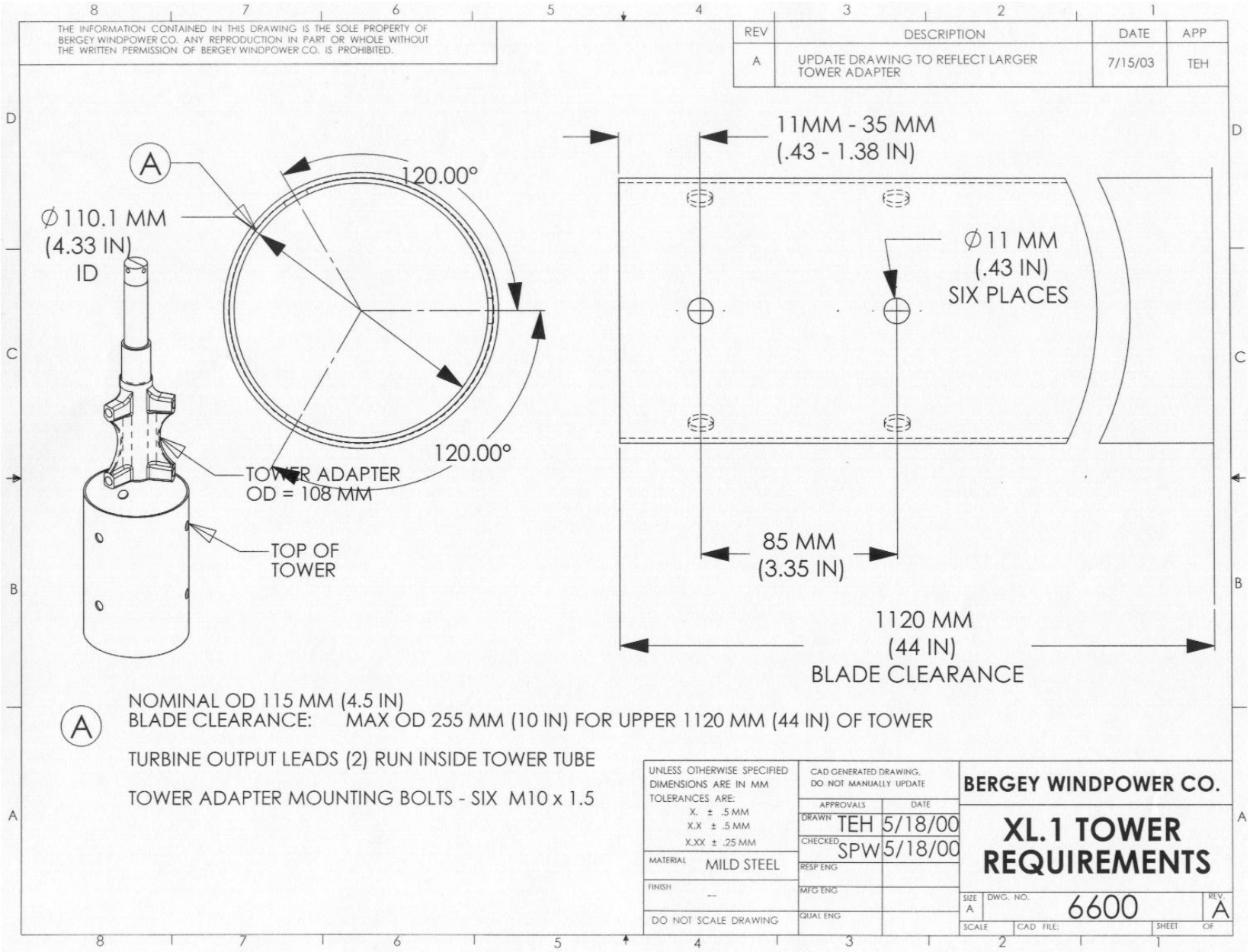
Tower Climbing: On non-tilting towers, provisions must be made to allow the tower to be climbed for inspections and possible maintenance. Climbing pegs should be removable if they do not meet the blade clearance requirement. On lattice-type towers, we recommend the use of horizontal laterals to facilitate climbing. We recommend the use of anti-fall devices for towers requiring climbing.

Materials: We recommend low-carbon steel towers, with careful attention given to weld quality. Stress risers and brittle materials must be avoided because of the possibility of fatigue and cracking. We do not recommend aluminum be used due to the risk of cracking. Fasteners should be U.S. Grade 2 or Grade 5 or equivalent.

Finish: We recommend hot-dip galvanizing after fabrication

Pipe / Tubing Sizes: The following standard steel tubing sections have ID and OD dimensions that are compatible with the BWC XL.1 (shipped after Sept. 2003):

4.5 in. OD, 0.095 in. wall thickness
4 in. pipe, 0.120 in. wall thickness
120 mm OD, 5.0 mm wall thickness
120 mm OD, 2.5 mm wall thickness


THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF BERGEY WINDPOWER CO. ANY REPRODUCTION IN PART OR WHOLE WITHOUT THE WRITTEN PERMISSION OF BERGEY WINDPOWER CO. IS PROHIBITED.
REV | DESCRIPTION | DATE | APP
A | UPDATE DRAWING TO REFLECT LARGER TOWER ADAPTER | 7/15/03 | TEH
A
Ø110.1 MM (4.33 IN) ID
120.00°
120.00°
TOWER ADAPTER OD = 108 MM
TOP OF TOWER
11MM - 35 MM (.43 - 1.38 IN)
Ø11 MM (.43 IN) SIX PLACES
85 MM (3.35 IN)
1120 MM (44 IN) BLADE CLEARANCE
A NOMINAL OD 115 MM (4.5 IN)
BLADE CLEARANCE: MAX OD 255 MM (10 IN) FOR UPPER 1120 MM (44 IN) OF TOWER
TURBINE OUTPUT LEADS (2) RUN INSIDE TOWER TUBE
TOWER ADAPTER MOUNTING BOLTS - SIX M10 x 1.5
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM
TOLERANCES ARE:
X. ± .5 MM
X.X ± .5 MM
X.XX ± .25 MM
MATERIAL MILD STEEL
FINISH ---
DO NOT SCALE DRAWING
CAD GENERATED DRAWING, DO NOT MANUALLY UPDATE
APPROVALS | DATE
DRAWN TEH 5/18/00
CHECKED SPW 5/18/00
RESP ENG
MFG ENG
QUAL ENG
BERGEY WINDPOWER CO.
XL.1 TOWER REQUIREMENTS
SIZE A | DWG. NO. 6600 | REV. A
SCALE | CAD FILE: | SHEET OF